Does biochar improve soil function and crop growth ?

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Introduction

The use of biochar as an organic soil amendment has been widely investigated and promoted for the improvement of agricultural soil, and as a means to promote plant growth. Among its many reported benefits, biochar is claimed to promote plant growth, improve soil water-holding capacity, alter soil microbial diversity and population dynamics and reduce nutrient leaching loss, (Verheijen et al. 2010; Lehmann et al. 2011; Spokas et al. 2012; Bierderman and Harpole 2013).

Methodology

We applied 47 Mg ha^{-1} Acacia biochar to a Bleached Mottled Grey Kurosol (Planosol) in a high input commercial apple production system in Tasmania, Australia. The biochar was acacia whole tree green waste that had undergone pyrolysis in a continuous flow kiln at temperatures up to 550 ℃ for 30–40 min. The trial design was a randomised complete block in which each block consisted of 3 trees. The biochar had a pH of 6.4 with concentrations of nutrient as follows: 8.93 % organic C, 3 mg kg^{-1} NH4 $^{+}$, 1 mg kg-1 $NO_3{}^{-}$, 234 mg kg^{-1} extractable P and 1117 mg kg^{-1} K.
Soil physical properties and water relations were determined by *in situ* tension infiltrometers, desorption and evaporative flux on intact cores, pressure chamber analysis at −1,500 kPa, and wet aggregate sieving. The pore size distribution of the biochar was determined by scanning electron microscope and mercury porosimetry. Three Tranzflo passive-wick flux meters (Gee et al., 2009) were installed in each of two adjacent biochar and control plots to measure nutrient leaching from the base of the A1 horizon. The flux meters consisted of a 200-mm-diameter × 250-mm-deep intact soil core from the A1 horizon installed above a 65-cm-long fiberglass wick that was connected to the soil via a sand/diatomaceous earth pad. The Hydrus 2D/3D suite of models were parameterized using measured soil water retention data and calibrated using field data collected over a 596-d period. The model was used to explore the effect of current management practices on nitrate leaching and explore options for reducing irrigation and nitrate loss.
Trees were measured for; girth, trunk cross sectional area, blossom clusters, fruit yield, colour, and firmness. Tree water use was measured by sapflow, monthly gas exchange and leaf water potential measurements were carried out on the same day on trees installed with the sapflow probes from November 2012 to April 2013. Photosynthetic capacity (A1500) and stomatal conductance (gs) were measured using a Li-Cor 6400 infrared gas analyser.

Results

Despite the biochar being dominated by pores within the PAWC range, biochar application had no significant effect on; soil moisture content, unsaturated hydraulic conductivity <-0.25 kPa, van-Genuchten retention parameters, drainable porosity (–1.0 kPa and -10 kPa), field capacity, PAWC, or aggregate stability. However, the biochar amended soil appeared to have attracted earthworms, whose burrowing appeared to have been responsible for the increased near saturated hydraulic conductivity and total porosity, associated with the creation of large (> 1200 µm) macropores.
Biochar application resulted in significantly greater loss of potassium and phosphorous from the topsoil, however biochar application had no significant effect on nitrate leaching.Leaching accounted for loss of between 53 % to 78 % of the applied nitrogen, 5 % to 11 % of the applied phosphate, and 69 % to 112 % of the applied potassium from the topsoil (Figure 1).
Application of biochar resulted in modest changes in the type and function of microbial communities, however the relative abundance of soil bacteria was unaffected. Biochar application also had no significant effect on fruit yield or fruit quality, photosynthetic capacity, leaf nutrient concentration, or daily tree water use.

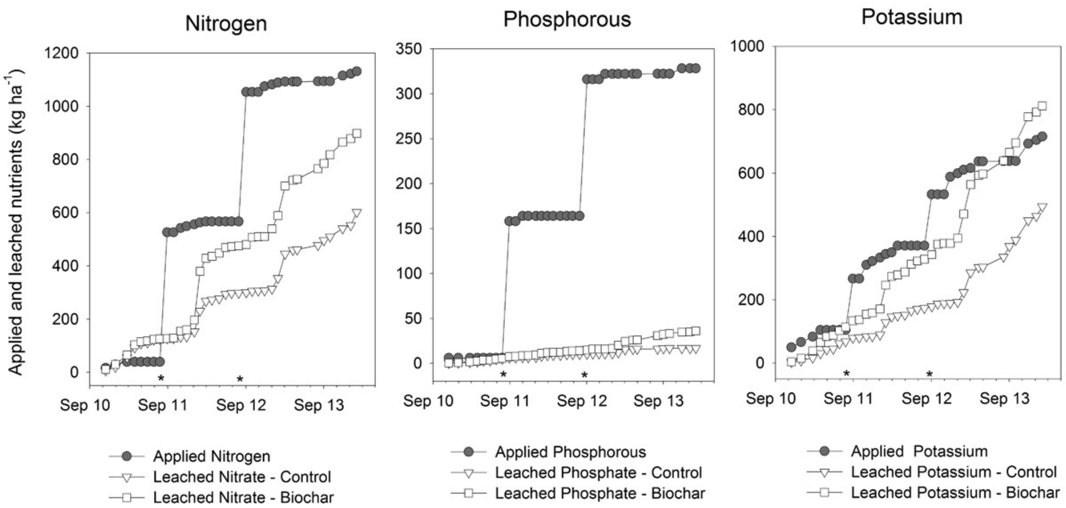

Fig. 1. Comparison between the cumulative applied nutrients and cumulative nutrients lost below the A1 horizon for the biochar and control treatments. Values refer to the tree row. Stars indicate the timing of green fowl manure application.

Simulations demonstrated the orchard was inherently and profoundly ‘leaky’ with between 15 and 33% of the average annual rainfall being lost via runoff and deep drainage under rainfed conditions Modelling showed that the current young trees resulted in loss of 38.1 kg N ha^{-1} yr^{-1} or 46% of the applied nitrate, and 34.6 cm yr^{-1} of rainfall and irrigation as drainage below 2.0 m depth. For mature trees, model scenarios predicted that converting from sprayers to drippers, would reduce the required irrigation by 44%, reduce nitrate requirement by 21%, and reduce deep drainage and nitrate leaching by 37%. Deficit-based irrigation and fertigation scheduling had minimal effect on the amount of deep drainage and nitrate leaching.

Conclusion

Despite persistent claims to the contrary, we found that application of a single rate of acacia hardwood biochar within a commercial apple orchard, had no significant effect on soil hydrological function, soil water availability, nutrient retention, tree water use, tree growth, fruit quality, or fruit size. Application of biochar had significant negative consequences including reduced pH and increased leaching of phosphorus and potassium. Minor changes in soil density, earthworm abundance, and microbial communities were also observed.

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